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# Simulation in medical graduation: teaching of pharmacology

*Simulação realística no curso de medicina: o ensino da farmacologia*

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## ABSTRACT

**Introduction:** Medical education faces the significant challenge of making classes, especially in the basic cycle such as pharmacology, more dynamic. This new pedagogical scenario should promote problem-solving and practical-theoretical integration, essential for medical training. In this context, active methodologies have emerged as effective tools to catalyze this transformation. Among these methodologies, realistic simulation has stood out for its ability to make classes more dynamic and interactive, increasing student participation and facilitating the practical application of theoretical concepts. The use of realistic simulation in basic sciences, such as pharmacology, is particularly relevant, especially considering the limitations imposed by the ban on the use of animals in educational practices, which previously played a central role in medical training.

**Objective:** To validate and promote the use of realistic simulation in pharmacology education, aiming to explore its impact on students' learning and memorization.

**Methods:** Students from the fifth semester of the medical course who were enrolled in the pharmacology class (n=131) were invited to participate in the study. To evaluate the effectiveness of using realistic simulation compared to reading clinical cases, practical classes from both groups of the subject were utilized to teach methodologies in addition to the theoretical class to which both groups were submitted. Learning and memorization were then compared using evaluation questionnaires administered immediately after the practical classes and 15 days later. The topics addressed were asthma and diabetes mellitus.

**Results:** The diabetes mellitus simulation improved learning immediately after the class ($U=1075$, $p<0.001$) but did not enhance the students' long-term memory ($U=1022$, $p=0.1490$). The asthma simulation did not improve learning ($U=1574$, $p=0.4505$) or long-term memory ($U=1222$, $p=0.3222$). A global analysis of the experience showed that realistic simulation improved learning of the proposed topics ($U=5282$, $p<0.01$); however, when comparing the proportion of correct answers per question according to the teaching methodology, no statistically significant difference was found ($p=0.09$).

**Conclusion:** It was found that realistic simulation has a positive effect on practical pharmacology classes, contributing to more effective and dynamic learning. These results suggest that realistic simulation can be a valuable tool for teaching basic sciences in medical education.

**Keywords:** medical education, pharmacology, realistic simulation, active methodology.

## RESUMO

**Introdução:** *A graduação em medicina possui o grande desafio de tornar as aulas, sobretudo do ciclo básico, como a farmacologia, mais dinâmicas. Esse novo cenário pedagógico deve incentivar a resolução de problemas e a integração prática-teórica, essencial para a formação médica. Nesse contexto, as metodologias ativas têm emergido como ferramentas eficazes para catalisar essa transformação. Entre essas metodologias, a simulação realística tem se destacado por sua capacidade de tornar as aulas mais dinâmicas e interativas, aumentando a participação dos alunos e facilitando a aplicação prática dos conceitos teóricos. A utilização da simulação realística nas ciências básicas, como a farmacologia, é particularmente relevante, especialmente considerando as limitações impostas pela proibição do uso de animais em práticas educacionais, que antes desempenhavam um papel central na formação médica.*

**Objetivo:** *Validar e promover a utilização da simulação realística no ensino da farmacologia, com o intuito de explorar seu impacto na aprendizagem e na memorização dos alunos.*

**Métodos:** *Foram convidados a participar do estudo alunos do quinto período do curso de medicina que estavam cursando a disciplina de farmacologia (n=131). Para avaliar a eficácia do uso da simulação realística em comparação com a leitura de casos clínicos, foram utilizadas as aulas práticas das duas turmas da disciplina para o ensino das metodologias em complemento à aula teórica a que ambos os grupos foram submetidos e, assim, comparar entre eles a aprendizagem e memorização através de questionários de avaliação aplicados imediatamente após o término das aulas práticas e 15 dias depois. Os temas abordados foram a asma e a diabetes mellitus.*

**Resultados:** *A simulação de diabetes mellitus melhorou a aprendizagem logo após a aula ($U=1075$, $p< 0.001$) e não melhorou a memória de longo prazo dos alunos ($U=1022$, $p=0.1490$). A simulação de asma não melhorou a aprendizagem ($U=1574$, $p=0.4505$) e a memória a longo prazo ($U=1222$, $p=0.3222$). Uma análise global da experiência mostrou que a simulação realista melhorou a aprendizagem dos temas propostos ($U=5282$, $p<0.01$), entretanto quando se compara a proporção de acertos por questão de acordo com a metodologia de ensino, nenhuma diferença estatisticamente significativa foi encontrada ($p=0.09$).*

**Conclusão:** *Verificou-se que a simulação realística tem um efeito positivo nas aulas práticas de farmacologia, contribuindo para uma aprendizagem mais eficaz e dinâmica. Esses resultados sugerem que a simulação realística pode ser uma ferramenta valiosa para o ensino das ciências básicas na graduação em medicina.*

**Palavras-chave:** *educação médica, farmacologia, simulação realística, metodologia ativa.*

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## INTRODUCTION

Medical education, as all higher education in health, has been the target of great dissatisfaction due to the reality presented in recent decades, thus leading to several evaluations of the teaching-learning system and, consequently, proposals for improvements[1]. Most of the criticism is related to fragmented teaching, distance from reality, appreciation of technical information to the detriment of the development of issues related to ethics, humanization of care and patient/population needs[2].

One of the main elements that perpetuates the fragility of the system is passive teaching, centered on the figure of the teacher, which prioritizes the transmission of previously elaborated knowledge instead of stimulating an environment where skills and abilities can be developed through situations that instigate student thinking and, consequently, build knowledge through their own perception[3,4].

Associated with the large deficit in teaching structure, the process takes on even greater proportions when added to the observed lack of motivation and engagement of students of this generation, which directly impact attendance, performance and problem-solving ability[4].

The solution to face the current scenario since then has been the adoption and development of an environment where investigation within the teaching environment is favored, above all, based on a theoretical-practical articulation[3]. Several projects emerged as a proposal to break this scope of teaching and for this new teaching methodologies were developed, physical spaces re-signified and curriculums updated[5].

Through active teaching methodologies and student-centered tools, learning happens through exposure to real problems and situations – the same ones that students will encounter in their daily practice once they graduate. Therefore, they are based on the assumption of using creative and challenging activities to encourage the student's active participation and critical thinking, therefore, increasing interest and memory retention. Problem-based learning, games, portfolios, podcasts, quiz solving, surveys, flipped classroom, virtual reality, realistic simulation and clinical cases are examples of active teaching methods[4-7].

The basic sciences of health courses, which include pharmacology, also needed to adapt to the use of active methodologies, above all, to be able to work on essential and complex concepts in a clinical and practical way[4]. In pharmacology, the favoring of the study of the therapeutic effect of drugs in humans to the detriment of pharmacodynamics was observed[8]. Thus, we can observe that the focus on another branch of pharmacology allowed answering the aspirations of medical students regarding which treatment to use and how this treatment will produce the therapeutic effect in certain clinical conditions. A fact that contributed to this change of focus, even if indirectly, was the restriction/prohibition on the use of animals in undergraduate practical classes[9]. Therefore, pharmacology practical classes were filled with the resolution of pharmacological clinical cases and discussion of scientific articles.

Among the mentioned methodologies, realistic simulation, which consists of an interdisciplinary practice that provides more autonomy to the student, began in the 1960s in Canada and in Brazil in the 1990s[10,11]. To carry out this methodology, automated simulators are used in controlled environments and/or simulated patients (actors/actresses) that allow the student to develop the chronology of patient care, communication, empathy and professional ethics before actually being in contact with a real patient[6,12,13]. Thus, simulation is considered a way to prevent medical malpractice and provide greater patient safety in the future[14].

Simulation-based training enhances the acquisition of clinical skills, decision-making development, and knowledge retention, especially in complex scenarios. Simulation provides a controlled and safe environment where students practice medical procedures and face realistic situations, elevating the quality of learning. Additionally, this method significantly contributes to strengthening the confidence and preparedness of future health professionals, allowing them to become familiar with essential clinical practices before engaging in real-life situations[14,15].

Many challenges must be overcome to build a teaching-learning process that gains students' trust, attention and dedication[17,18]. The main challenges of realistic simulation include the high costs of equipment implementation and maintenance, the need for specialized instructors, and the time dedicated to planning and conducting effective scenarios. Furthermore, simulation may, in certain cases, reduce realism, which can impact the transfer of skills to real clinical situations. These factors require innovative approaches to maximize the effectiveness of training, ensuring that simulation is a truly transformative educational experience applicable to clinical practice[14]. Thus, it is necessary to validate the methodologies employed, as well as to assess students' performance in the teaching-learning process following exposure to these methodologies.

Therefore, in the second half of 2022, in the pharmacology classes given to the 5th semester of the medical course at Faculdade de Minas (Faminas), Brazil, the following approaches were used in practical classes: clinical case reading and realistic simulations. The main objective was testing the hypothesis that students submitted to realistic situations would have better performance in learning assessment exercises than the ones submitted to the clinical case.

## METHODS

This study was conducted at Faculdade de Minas, Faminas BH, Brazil, after approval by the Research Ethics Commission, protocol number 5.378.824 (2021). All students attending the fifth semester were invited (n=131), which is the period when pharmacology lectures are conducted. In the beginning of the undergraduate period, students are randomly divided into two different classes to attend the lessons – class 1 and 2. The present study used the preexisting division in two different classes to compare the efficacy of learning between realistic simulation and clinical case reading.

The experiment took place during the pharmacology practical classes. The topics chosen for the lessons composing this study were pharmacology of diabetes mellitus and asthma, based on their importance to clinical practice.

The study happened in two moments: in the first moment class 1 was submitted to the practice lesson using realistic simulation about the diabetes mellitus case and class 2 was submitted to the clinical case reading; in a second moment the asthma lesson took place, where class 2 participated in a realist simulation and class 1 was submitted to the clinical case reading.

The research material sources were learning assessment exercises consisting of ten multiple choice questions applied after the practical lessons. These questions were used to evaluate the students' learning process and were not used as a grade to pass the subject. To assure the volunteers' autonomy and reduce vulnerability, all the questionnaires were anonymous.

The realistic simulations of diabetes and asthma took place in the realistic simulation lab. The students watched one of the monitors simulate the cases as a doctor and an actor as a patient in a medical appointment. All stages of a complete medical care appointment were carried out: anamnesis, physical examination, diagnosis, clinical decisions and recommendations to the patient. The simulations lasted about 40 minutes. Immediately after the simulation, the students were submitted to the individual questionnaire with the ten questions and had 15 minutes to answer. All the questions were created exclusively for the present study and were based on important pharmacology topics about diabetes and asthma.

The clinical case reading of diabetes and asthma took place in the classrooms. In the beginning of the practice a written clinical case of the proposed topic was presented and they had 5 minutes to read and once reading time finished all the cases were collected. The written clinical case consisted of the report of the case carried out in the realistic simulation, with data from the physical examination and the proposed treatment. Immediately after the clinical case reading, the students were submitted to the same individual questionnaire applied to the simulation group and had also 15 minutes to answer.

The students previously had a theoretical class on the subject before being submitted to the practical class related to one of the topics. Simulation groups and reading case groups had the same classes and the same teacher. The practices of this study respected the course schedule.

Before the first experiment, diabetes practical lessons, all the students were informed and invited to participate. At that moment all that accepted participating in the study signed the Informed Consent Form. To evaluate short-term learning, the numbers of right answers between simulation and reading were compared.

After participating in the realistic simulation or the clinical case reading, all the students were invited to repeat the questionnaires 15 days later and the right answers of each group were used to evaluate long-term learning. The hypothesis to be tested was that the simulation group would have better memory retention than the reading group.

Statistical analysis was performed using GraphPad Prism® 8 software. The results of the number of correct answers were analyzed by Anderson-Darling normality and lognormality test followed by the Mann–Whitney, since the data did not fit in a Gaussian distribution and the variances between groups were not homogenous. These data are presented as median ± interquartile range (IQR). To compare the proportion of correct answers between the realistic simulation methodology and case reading, the Chi-square test was used for each question of the questionnaire. All statistical analyses were conducted at a 95% confidence level.

## RESULTS

### Diabetes mellitus lesson

Students submitted to a realistic simulation class on diabetes mellitus performed better in the questionnaire applied immediately after the simulation ($U=1075$, $p< 0.001$) as compared to students who answered the same questionnaire right after reading the diabetes clinical case, as shown in Figure 2A. However, diabetes realistic simulation did not improve the students' long-term memory when comparing the reading of the diabetes clinical case ($U=1022$, $p=0.1490$), measured through the questionnaire applied 15 days after both classes, as shown in Figure 2B.

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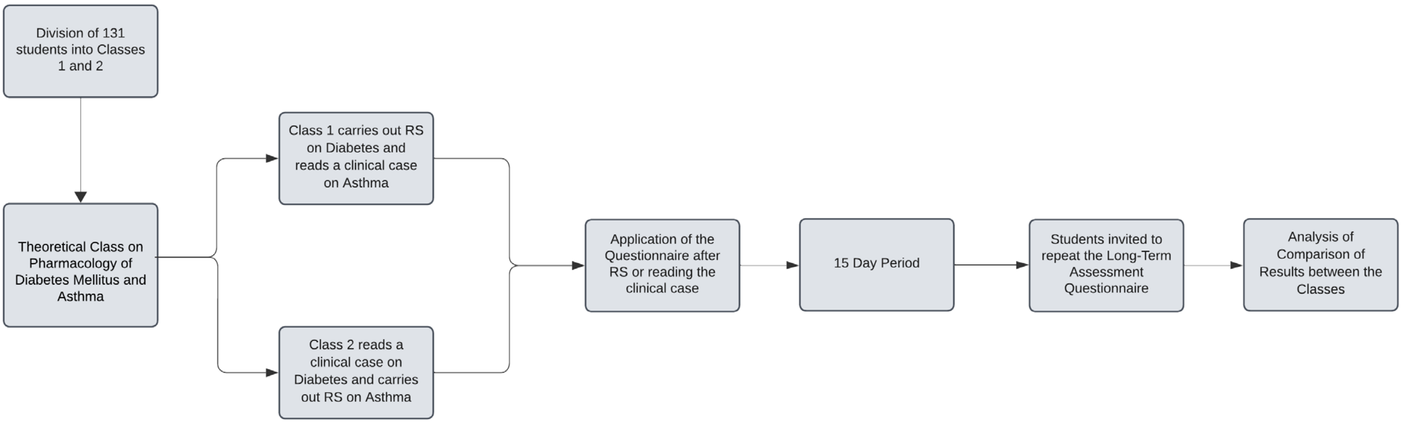
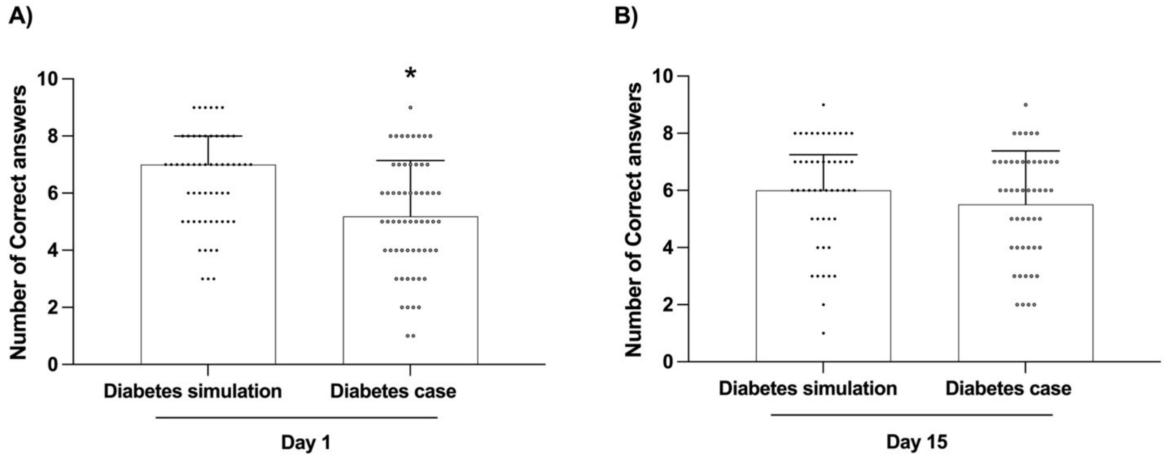
**Figure 1.** Experimental design used in this study (RS = realistic simulation).



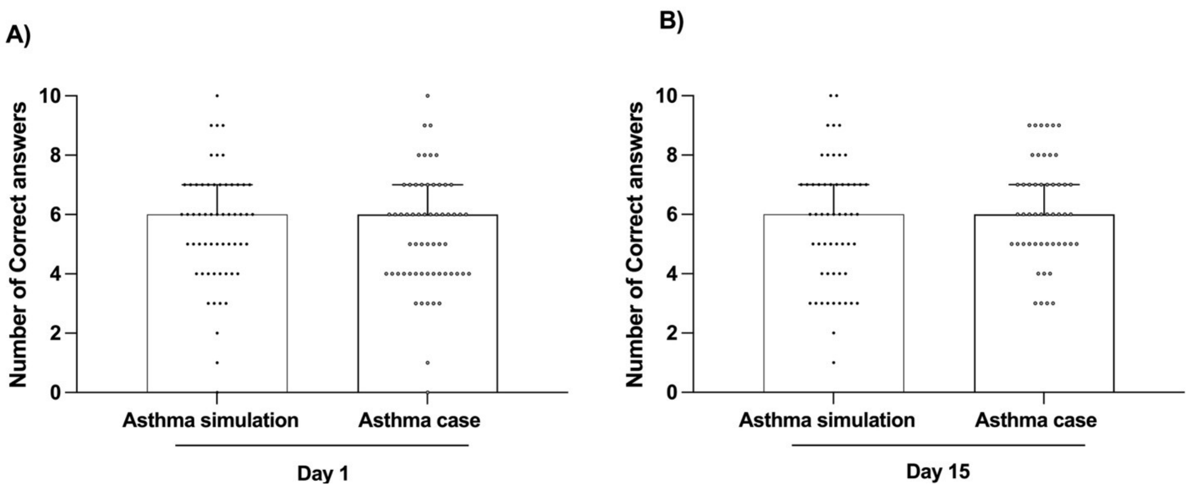

Source: Prepared by the authors.

**Figure 2.** Comparison between realistic simulation and clinical case reading in diabetes learning immediately after classes (A) and 15 days after classes (B).




Each bar represents median ± interquartile range for the number of correct answers. (A) *p<0.001, Anderson-Darling followed by Mann-Whitney test; n=57-60 per group. (B) p=0.1490, Anderson-Darling followed by Mann-Whitney test; n=49-50 per group.
Source: data from the study.

**Figure 3.** Comparison between realistic simulation and clinical case reading in asthma learning immediately after classes (A) and 15 days after classes (B).




Each bar represents the median ± interquartile range for the number of correct answers. (A) p=0.4505, Anderson-Darling followed by Mann-Whitney test; n=58-59 per group. (B) p=0.0322, Anderson-Darling followed by Mann-Whitney test; n=50-55 per group.
Source: data from the study.

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### Asthma lesson

Students submitted to a realistic simulation class on asthma did not perform better in the questionnaire applied immediately after the simulation (U=1574, p=0.4505) as compared to students who answered the same questionnaire right after reading the asthma clinical case, as shown in Figure 3A. Similar results were observed when the questionnaire on asthma pharmacology was applied 15 days after the class, i.e., asthma realistic simulation did not improve the students' medium-term memory when compared with the reading of the asthma clinical case (U=1222, p=0.3222), as shown in Figure 3B.

### Joint analysis of classes (diabetes and asthma)

Students submitted to a realistic simulation class on diabetes and asthma performed better in the questionnaire applied immediately after the simulation (U=5282, p<0.01) as compared to students who answered the same questionnaire right after reading the clinical cases (diabetes and asthma), Figure 4.

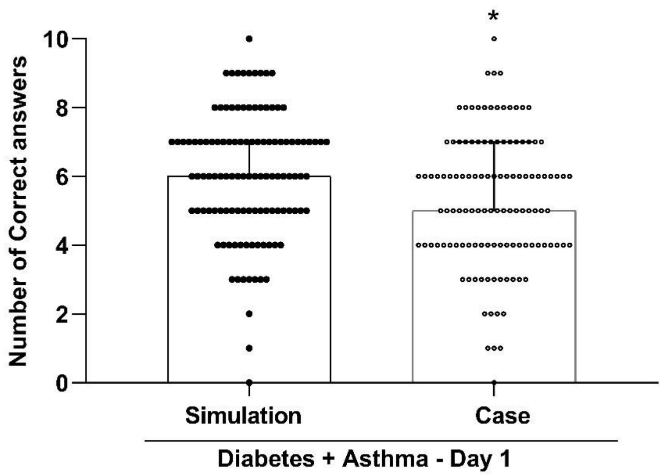
When comparing the accuracy rate of each question according to the methodology employed, either realistic simulation or case reading, no statistically significant difference was found (p=0.09), as shown in Table 1.

## DISCUSSION

Realistic simulation has proven to be an effective tool in medical education, particularly in the development of clinical skills among pre-clinical students. Compared to more traditional teaching methods, the use of realistic simulation scenarios allows students to practice and improve communication skills, clinical reasoning, and problem-solving in a controlled and safe environment. This type of training is essential for students who often feel anxious and lack confidence in their clinical abilities before starting real-life practices[19,20].

Another relevant aspect of using realistic simulation is the opportunity to practice teamwork and interpersonal interaction, which are fundamental competencies for future healthcare professionals. Simulation facilitates the acquisition of these skills, as it frequently involves care scenarios that require coordination and communication among participants. Recent studies show that these teaching methodologies contribute not only to the development of technical skills but also to improving collaborative work abilities and students' confidence in intensive care environments. This approach has

**Figure 4.** Comparison between realistic simulation and clinical case reading in diabetes and asthma learning immediately after classes (day 1).




Each bar represents median ± interquartile range for the number of correct answers (*p<0.01, Anderson-Darling followed by Mann-Whitney test; n=115-119 per group).
Source: data from the study.

**Table 1.** Comparison of the accuracy rate (%) for each individual question in the realistic simulation and the case reading.

| | Diabetes - Day 1 | | Diabetes - Day 15 | | Asthma - Day 1 | | Asthma - Day 15 | |
|---|---|---|---|---|---|---|---|---|
| | Simulation | Case | Simulation | Case | Simulation | Case | Simulation | Case |
| Question 1 | 59 | 43 | 53 | 47 | 36 | 37 | 46 | 58 |
| Question 2 | 76 | 57 | 61 | 61 | 56 | 69 | 58 | 66 |
| Question 3 | 71 | 45 | 69 | 61 | 78 | 64 | 74 | 76 |
| Question 4 | 83 | 53 | 67 | 65 | 46 | 34 | 60 | 54 |
| Question 5 | 60 | 71 | 71 | 63 | 71 | 71 | 74 | 70 |
| Question 6 | 76 | 64 | 67 | 53 | 76 | 59 | 62 | 66 |
| Question 7 | 74 | 71 | 84 | 71 | 73 | 83 | 76 | 86 |
| Question 8 | 5 | 12 | 8 | 14 | 51 | 53 | 48 | 58 |
| Question 9 | 55 | 69 | 71 | 67 | 25 | 20 | 16 | 12 |
| Question 10 | 78 | 52 | 61 | 47 | 39 | 47 | 58 | 70 |

Source: data from the study.

been recognized for helping students transfer the knowledge gained more effectively to real clinical practices, promoting active and immersive learning[19,21].

Despite its numerous advantages, the implementation of realistic simulation in medical education presents challenges, including the high cost of equipment and the need for qualified facilitators. Moreover, the preparation and execution of simulations are processes that require careful planning and dedicated time, which can be a limitation in intensive medical curricula[14].

The results of this study showed that the use of realistic simulation improved the pharmacology learning process in medical students when compared to the reading of clinical cases. Students submitted to realistic simulation about diabetes had better performances with significant statistical differences when compared to the reading of diabetes cases.

The importance of practicing these methodologies in the medical field is widely discussed and there are many studies on the importance of simulation as a tool in medical education that examine different aspects, with correspondingly diverse results[21]. According to Fermozelli et al., an analysis of the students' point of view observed that most undergraduate students showed acceptance of the active methodology employed, greater motivation and ability to contextualize pathological processes[23]. Corroborating this study, Silva et al., also demonstrated through problem-based learning that student participation, the incentive for reasoning, the application of concepts to their reality allowed a constructive exchange between teacher-student and a dynamic and evolving teaching-learning process[24].

However, another study described that the traditional methodology was the one that was the most accepted and best met the expectations of students[25]. The difficulty of acceptance may be related to the fact that not everyone is prepared for this type of methodology and sometimes they feel lost in their search for knowledge. Another contributing factor to this scenario is the low experience of some teachers with active learning methodologies, which reflects on the difficulty of executing it and ends up harming the transfer and acquisition of knowledge[26]. Better considerations about student role, cost, time, and setting must be made to establish how these educational practices can best occur[27].

The work results are in agreement with the study of Ferreira et al., which observed improved results with the association of realistic simulation and traditional classes when teaching patient risk classification to medical and nursing students. These results are in line with other studies that point to simulation as an effective teaching-learning strategy when compared to traditional teaching[26,28]. Simulation has also been shown to be a bridge to the existing gap between theory and practice[27].

Dourado and Giannella evaluated the use of cardiopulmonary resuscitation simulation-based learning in continuing medical education through a semi-structured interview. It was observed that teachers and students reported that simulation-based teaching favored the acquisition and improvement of knowledge, since there was a greater approximation between theory and practice, as isolated learned concepts could be rescued within the simulated contexts. They also reported that the discussions and the possibility of repetition allowed by the simulations helped in memorizing protocols[29].

However, the authors discuss the difficulty perceived by teachers for students to face the simulation as a real environment, especially when using simulation mannequins (hybrid simulation), because they are unable to use it as an opportunity to practice a virtual scenario that can truly happen in a real situation and are not accustomed to participating in this type of methodology. Another relevant factor addressed by them is that the literature shows the sooner students start practice simulation-based learning, the greater is the development in semiotics and the acquisition of communication skills. The study indicates as a challenge the necessary teachers' willingness to deal with students of different levels of knowledge and practice[29].

The works of Goulart Alves et al. and do-Nascimento & Magro showed that the use of simulations increased knowledge in nursing intubation actions in trained professionals and in medication administration in an undergraduate nursing course, respectively, using pre and posttests; in both studies the performance gain was evidenced after the simulations through the posttest[30,31].

The same result was not observed in the asthma lesson: realistic simulation did not show better individual results when compared to the reading of cases. The authors considered that the asthma outcomes must have been influenced by the proximity to the formative assessment at the end of the semester, a fact that may have made both groups more prepared on this topic.

Following the course schedule could be considered one the limitations of this study, what may have influenced the asthma simulation. Furthermore, not having a student staging the simulation can be a limiting factor to the study, but a monitor was chosen to stage the simulations to prevent important aspects of the health-disease process from not being investigated and approached. Comparing individual students' results could be a good way of evaluating learning improvement; however, we chose not to identify the questionnaires to try to spare them any kind of embarrassment. Although we did not do a simulation debriefing before the application of the questionnaire, this could be another tool to improve learning.

Although realistic simulations create a safe place to develop communication skills, leadership, teamwork, help in the assimilation of important topics and constitute a safe environment for errors, there is great resistance from the faculty in adopting this method of teaching[26,28]. Furthermore, it has been described that Brazil has a lower use of simulations than is considered ideal when compared to other countries[32]. Thus, the scientific basis of the simulation effectiveness could be a factor to increase adherence to this teaching method.

This work did not measure the student's satisfaction and preference for both class formats. However, the authors realized that the realistic simulation generated greater engagement in the students, who after the class wanted to clear up doubts about the clinical case staged and about the adopted conducts. On the other hand, the same interaction did not exist after the clinical case reading.

Memory retention was not improved for the realistic simulation regarding the topics of diabetes mellitus and asthma. The same questionnaire applied immediately after the lessons on day 1 were repeated after 15 days to evaluate the long-term memory. It is known that memory is not a unitary process and has different phases/stages for acquisition, short-term memory, long-term memory formation and consolidation, maintenance, retrieval, extinction, reconsolidation. Although there are many gaps in knowledge about the cell and molecular mechanisms related to long-term memory maintenance, it is known that the brain-derived neurotrophic factor (BNDF) plays a key role in memory storage persistence by controlling late memory consolidation in the hippocampus. A series of studies revealed that a phase dependent on late protein synthesis, around 12 h after training, is necessary for memory persistence[33]. The time between applications was based on the time required for neurogenesis/protein synthesis to occur.

## CONCLUSION

This study found a positive effect of the use of realistic simulations on practical pharmacology classes. This effect was identified by comparing two groups of students after both had the same lecture classes and then participated in the application of two different practical class methodologies: students who participated in realistic simulation and students who were submitted to a written clinical case of two different topics (diabetes and asthma). The students' results were better in the simulation. Thus, the potential of realistic simulation as a tool to enhance the learning process in basic sciences is evident. More studies with more solid research designs and valid measuring instruments are needed for this tool to be increasingly incorporated into practical classes, especially in the basic sciences.

## AUTHORS' CONTRIBUTIONS

Adonay Felipe Pereira Santos contributed to the conduction of the experiments and writing of the manuscript. Ângelo Gabrielli assisted in writing the manuscript and conducting the experiments. Anna Carolina Lustosa Lima reviewed the statistical analysis and collaborated with the writing of the manuscript. Gisele Eva Bruch reviewed and collaborated with the writing of the manuscript. Ana Flávia Santos Almeida conceived, conducted and wrote the manuscript.

## CONFLICTS OF INTEREST

The authors declare no conflicts of interesst.

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## REFERENCES

1. COSTA, Nilce Maria da Silva Campos. Docência no ensino médico: por que é tão difícil mudar? Revista Brasileira de Educação Médica, v. 31, p. 21-30, 2007.
2. BATISTA, Sylvia Helena da Silva. A interdisciplinaridade no ensino médico. Revista Brasileira de Educação Médica, v. 30, p. 39-46, 2006.
3. CARABETTA JR, Valter. Metodologia ativa na educação médica. Revista de Medicina, v. 95, n. 3, p. 113-121, 2016.
4. MARCONDES, Fernanda Klein. Experiências no uso de metodologias ativas no ensino de Fisiologia, em um curso de graduação em Odontologia. III Simpósio Internacional de Inovação em Educação, p. 1-10, 2015.
5. MORÁN, José. Mudando a educação com metodologias ativas. Coleção de mídias contemporâneas. Convergências midiáticas, educação e cidadania: aproximações jovens, v. 2, n. 1, p. 15-33, 2015.
6. MORAES, MAA; ANGELI, OA. Desempenho dos pacientes simulados no exercício de avaliação da prática profissional. Saúde (Santa Maria), Vol. 42, n. 2, p. 167-174, Jul/Dez. 2016.
7. ROSSINI, EB; PEREIRA JÚNIOR, GA. Simulação em saúde para ensino e avaliação: conceitos e práticas. Ed. Cubo. São Carlos. 2021.
8. FUCHS, F; WANNMACHER, L; VICTOR, M. O Ensino da Farmacologia Médica direcionado à realidade: exemplo de uma experiência pioneira. R. Bras. Educ. Med. Rio de Janeiro, 12(2): 41-76, maio/ago. 1988.
9. MAGALHÃES, Marcos; ORTÊNCIO FILHO, Henrique. Alternativas ao uso de animais como recurso didático. Arq. ciênc. vet. zool. UNIPAR, p. 147-154, 2006.
10. TRONCON, LEA. O emprego de pacientes simulados e padronizados na avaliação prática de habilidades clínicas. Avaliação Prática de Habilidades Clínicas em Medicina. São Paulo. Atheneu; p.75-87. 2012.
11. BONAMIGO, EL; DESTEFANI, AS. A Dramatização como estratégia de ensino da comunicação de más notícias ao paciente durante a graduação médica. Rev. Bioética. set/dez. 18(3):725-742. 2010.
12. MORAES, MAA; MARVULO, MML; BRACCIALLI, LAD; COSTA, MCG. O uso da simulação como estratégia avaliativa na graduação em saúde. Avaliação nos Cursos de Medicina e Enfermagem: perspectivas e desafios. Curitiba: CRV. p.143-162. 2012.
13. OSSINI, EB. Expansões da teatralidade: a participação de atores na prova de admissão de residentes e de especialistas no Hospital das Clínicas de São Paulo e no Revalida do Governo Federal. 2020. 100 f. Dissertação (Mestrado) - Programa de Pós-graduação em Artes Cênicas, Escola de Comunicação e Artes, Universidade de São Paulo, São Paulo. 2020.
14. ELENDU, C; AMAECHI, DC; OKATTA, AU; AMAECHI, EC; ELENDU, TC; EZEH, CP; ELENDU, ID. The impact of simulation-based training in medical education: A review. Medicine. 103, n. 27, p. e38813, 2024.

15. HERRERA-ALIAGA, E; ESTRADA, LD. Trends and innovations of simulation for twenty first century medical education. Frontiers in public health. v. 10, p. 619769, 2022.

16. HUGHES, KE; CAHIR, TM; NORDLUND, D; KEIM, SM; HUGHES, PG. Fear Not: Utilizing Simulation for Medical Malpractice Education. J Med Educ Curric Dev. 2022.

17. DOMENEGHINI GL., SANTOS, BZ; ALVES, BGC; DAL BOSCO, L. Relato do uso de jogo educacional na monitoria de fisiologia do ciclo cardíaco. Anais do 10 Salão Internacional De Ensino, Pesquisa e Extensão - SIEPE Universidade Federal do Pampa. 2018.

18. LIMA, LF; MOREIRA, OC; CASTRO, EF. Novos olhares sobre o ensino da Fisiologia Humana e da Fisiologia do Exercício. Revista Brasileira de Prescrição e Fisiologia do Exercício. v. 8, n. 47, p.507-513, jun. 2014.

19. LATEEF, F. Simulation-based learning: Just like the real thing. Journal of emergencies, trauma, and shock, v. 3, n. 4, p. 348-352, 2010.

20. CHERNIKOVA, O. Simulation-based learning in higher education: A meta-analysis. Review of educational research, v. 90, n. 4, p. 499-541, 2020.

21. SALEEM, M; KHAN, Z. Healthcare Simulation: An effective way of learning in health care. Pakistan Journal of Medical Sciences, v. 39, n. 4, p. 1185, 2023.

22. PLCH, L; BARVÍK, D; ZOUNEK, J. Perception, beliefs, and attitudes towards simulation-based learning in health care students: Scoping review protocol. International Journal of Educational Research, v. 117, p. 102113, 2023.

23. FERMOZELLI, JA; CESARETTI, MLR; BARBO, MLP. Blended learning strategies in teaching general pathology at a medical course. J Bras Patol Med Lab, v. 53, n. 3, p. 202-209, June. 2017.

24. SILVA, RP; CAMACHO, ACLF; SILVA, MAP da; MENEZES, HF de. Strategies for the use of active methodology in the training of nursing academics: experience report. Research, Society and Development. v. 9, n. 6. 2020.

25. DEUS, JM; NONATO, DR; ALVES, RRF, SILVA, MMM., BOLLELA, AFAVR. Aula centrada no aluno versus aula centrada no professor: desafios para mudança. Rev. bras. educ. med. 38 (4). Dez. 2014.

26. YAMANE, MT; MACHADO, VK; OSTERNACK, KT; MELLO, RG. Simulação realística como ferramenta de ensino na saúde: uma revisão integrativa. Rev Espac Saúde, v. 20, n. 1, p. 87-107, 2019.

27. RUTHERFORD-HEMMING, T; HERRINGTON, A; NEWSOME, L. The Use of Simulation-Based Education with New Graduate Nurses in the Emergency Department and Acute Care Settings: A Scoping Review. The Journal of Continuing Education in Nursing, v. 53, n. 7, p. 301-306, 2022.

28. FERREIRA, RPN; GUEDES, HM; OLIVEIRA, DWD; de MIRANDA, JL. Simulação realística como método de ensino no aprendizado de estudantes da área da saúde. Revista de Enfermagem do Centro-Oeste Mineiro, v. 8, 2018.

29. DOURADO, ASS; GIANNELLA, TR. Ensino baseado em simulação na formação continuada de médicos: análise das percepções de alunos e professores de um Hospital do Rio de Janeiro. Revista Brasileira de Educação Médica, v. 38, p. 460-469, 2014.

30. DO-NASCIMENTO, MS; MAGRO, MCS. Simulação realística: método de melhoria de conhecimento e autoconfiança de estudantes de enfermagem na administração de medicamentos. Revista Mineira de Enfermagem, v. 22, p. 1-5, 2018.

31. ALVES, MG; MORAIS, CCP; de OLIVEIRA, JM; SILVA, AT; PEREIRA, VOS; DALRI, MCB. Aula simulada no ensino de ações de enfermagem na intubação. Journal of Nursing UFPE/Revista de Enfermagem UFPE, v. 12, n. 3, 2018.

32. FERREIRA, C. Impacto da metodologia de simulação realística, enquanto tecnologia aplicada a educação nos cursos de saúde. Anais do Seminário Tecnologias Aplicadas a Educação e Saúde, 2015.

33. BEKINSCHTEIN, P; CAMMAROTA, M; MEDINA, JH. BDNF and memory processing. Neuropharmacology, v. 76, p. 677-683, 2014.